A NEW METHOD *of* SEWAGE DISPOSAL

CHEMICAL DEPARTMENT
LIME
THE UNIVERSAL REAGENT

BULLETIN No. 200
NATIONAL LIME ASSOCIATION
WASHINGTON, D. C.

Among the many and varied uses of lime, which cause it to rank as a universally essential chemical re-agent, few are more important than its use as an aid in effecting purification of impure natural waters and trade wastes.

That this use may be extended to the treatment of municipal sewage is indicated by the subject matter of this bulletin.

A NEW METHOD *of* SEWAGE DISPOSAL

A Progress Report On a New Development In This Important and Essential Field of Endeavor, Presented to Those Who Are Interested In Safeguarding the Health of Their Community

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Presses of
W. C. HILL PRINTING CO.
Richmond, Va.

INTRODUCTORY

THE PROBLEM of the proper treatment and disposal of sewage is of paramount importance to the officials and citizens of every muncipality. Its importance is due to the fact that one of the fundamental laws of health is proper sanitation and elimination (so far as possible) of sources of bacterial infection. Many epidemics have been definitely traced to sewage contamination, which proves conclusively that raw sewage cannot be discharged directly into water courses without the possibility of endangering the health of the community.

Primitive methods of home treatment may be effective up to a certain point, but in any growing city the problem of a municipal sewage disposal plant sooner or later presents itself and becomes a more vital issue as the number of persons affected increases. Eventually the community must make some attempt to properly solve the problem, and in large cities it is an absolute necessity that adequate disposal plants be maintained without interruption. As this always involves the expenditure of municipal funds, it is highly important that a disposal plant be as economical as is consistent with efficient sanitation—the health of the citizens being of first importance.

The only open question is: Which method will be the best adapted to local conditions and will provide the best means of safe-guarding the health of the community?

In presenting a review of methods of sewage disposal now in general use and directing attention to a new method, the National Lime Association does so in recognition of the fact that the new method here presented employs lime as one of its essentials. The interest which our Association has in this commodity has led to an investigation of the subject, but in placing these matters before the public we desire to put the new method of sewage disposal upon its own merits, and we ask consideration of it only in so far as the principles and methods employed will stand the acid test of investigation and experience. We believe that it has considerable merit and desire that it be investigated closely by engineers and sanitary officers who may be qualified to pass upon its merits.

Outline of Methods of Treating Sewage.

A number of different processes for the treatment and purification of sewage have been devised and are in use. They may vary considerably in their manipulation, but, in the main, their efficiency de-

pends primarily upon bacterial action, sedimentation, filtration and disinfection, and the two principal results effected are:—

(1) The destruction of objectionable material in suspension or solution in the liquid.

(2) The removal and final destruction or utilization of the solid material.

Methods now in general use usually concentrate upon the first-named principle and the desired result is accomplished more or less completely in several different ways. These methods employ either oxidation alone or a combination of it with a reduction of the organic matter. Closely associated with the destruction of the organic matter is the necessity of destroying organisms in the sewage which may be producers of disease. Oxidation may be accomplished by bacterial action; by the use of certain chemicals, and by electro-chemical processes. By whatever means the oxidation may be affected the result is substantially the same—namely, the union of oxygen with unstable compounds—resulting in the formation of stable compounds (such as carbon dioxide), which are harmless. Reduction may be accomplished to a considerable degree by bacterial action and also by electro-chemical treatment. The result of proper reduction of organic compounds existing in the sewage is the formation either of harmless and unobjectionable compounds of a more simple chemical composition or the formation of compounds which may be more readily oxidized as above.

The completeness with which these two processes are accomplished is a measure of the efficiency of the method employed. In general, reduction and oxidation of sewage are not carried to the point of complete destruction of the organic matter, so that some material always remains in the form of a sludge, which must be removed and disposed of in some practical way, such as incineration or by use as fertilizer.

The usual practice is to combine reduction and oxidation methods with various methods of precipitation, settling, or filtration of the treated material. Various chemical re-agents are used and a number of mechanical appliances are employed, such as filter presses, filter beds, settling tanks, screens or other devices. This paper will not discuss methods of handling the sludge or residue resulting from the treatment of sewage, but will concern itself mainly with the application of principles employed in the treatment of raw sewage. The most important methods now in use are presented in tabular outline, in which it will be noted that the disinfection of the sewage is largely an incident of the direct destruction of organic material and of precipitation and filtration.

PRINCIPLES OF SEWAGE DISPOSAL			HOW RESULTS ARE OBTAINED IN THE VARIOUS SYSTEMS			
			Imhoff or Similar Septic Tanks	Chlorination Processes	Electro-Chemical, without Lime	Electro-Chemical, with Lime
Destruction of organic matter in Suspension or solution	Oxidation	Bacterial	Aerobic bacteria.			
		Chemical		Direct oxidation		
		Electro-Chemical			Weak oxidation by free oxygen.	Strong oxidation by nascent oxygen.
	Reduction	Bacterial	Anaerobic bacteria			
		Chemical				
		Electro-Chemical			Weak reduction by hydrogen.	Strong reduction by nascent hydrogen.
Disinfection		Chemical	Indirect result.	Indirect result.	Direct but weak oxidation.	Direct and controlled oxidation.
		Electro-Chemical			Some direct action of current.	Strong direct action of current.
Separation of solids	Precipitation	Chemical	Indirect result.	By lime.	By ferric hydrate	By lime.
	Filtration	Presses	As desired.	As desired.	As desired.	As desired.
		Sand beds				

Imhoff Tanks and Similar Devices.

These methods depend for their efficiency upon the action of both aerobic and anaerobic bacteria, the growth of which presents certain difficulties of control, due to a number of factors, such as changes in temperature, changes in chemical nature of the sewage, and other variations which it is difficult to regulate. It is doubtful if the degree of efficiency for a given set of conditions can be accurately foretold, and usually it must be determined by actual use. In general, a fairly high degree of purification is obtained together with the removal of a large percentage of suspended solids by these methods. (The effluent is usually precipitated or filtered and handled in some practical way).

There are indications that the action of aerobic bacteria is susceptible to a considerable amount of control and that they are largely instrumental in the purification affected. Further investigation along this line may be of considerable value in improving these processes. The difficulty sometimes encountered in completely removing turbidity from the effluent may also be overcome by further study and experimentation.

There is a considerable difference of opinion among sanitary engineers concerning the efficiency of these processes, some believing that they offer the best solution of sewage disposal problems and others inclining to the view that their operation is more or less a matter of conjecture, since they depend primarily upon "* * * the cultivation of delicate micro-organisms and bacteria, whose existance is affected by conditions, such as changes in temperature and the nature of the sewage which cannot be controlled."

"Chlorination," or Chemical Oxidation.

The introduction of chlorine or chloride of lime into the sewage results in the liberation of nascent oxygen, which attacks the organic matter in very much the same way as the oxygen produced by the action of bacteria. The term chlorination as applied in this connection is somewhat misleading, inasmuch as no actual chemical chlorination of the sewage takes place, the action being mainly one of disinfection through the destruction of objectionable bacteria and the oxidation of unstable compounds brought about by the liberated oxygen.

Electro-Chemical Treatment Without Lime.

Municipal installations for the treatment of sewage by electrolysis were made as early as 1893 and several plants of a more or less experimental nature have been operated in various cities in the United States. Changes in design and construction have effected improvements in

the results obtained, one plant having effected a bacterial removal of 86 per cent or over.

This process (which should not be confused with the Direct Oxidation Process—discussed in the next section of this paper) depends for its results upon the passage of an electric current between large iron electrodes suspended in the sewage. A high voltage is required because of the relatively poor conductivity of the raw sewage. The fact that the passage of the current between the electrodes depends upon the soluble salt content of the sewage makes this salt content a measure of the efficiency of the process. Since the amount of solids in solution is constantly changing, it may be safely said that the effect of the current is a variable quantity, which may or may not be adequate for the destruction of objectionable organic matter in the sewage.

The iron electrodes are rapidly attacked by raw sewage and the dissolved iron is converted into ferric hydrate by the action of the water and the oxygen which is liberated by electrolysis. (There may be some liberation of oxygen and hydrogen which will be available for sterilization.) The ferric hydrate so produced is capable of uniting with many of the organic compounds present and serves as a very effective coagulant and precipitant.

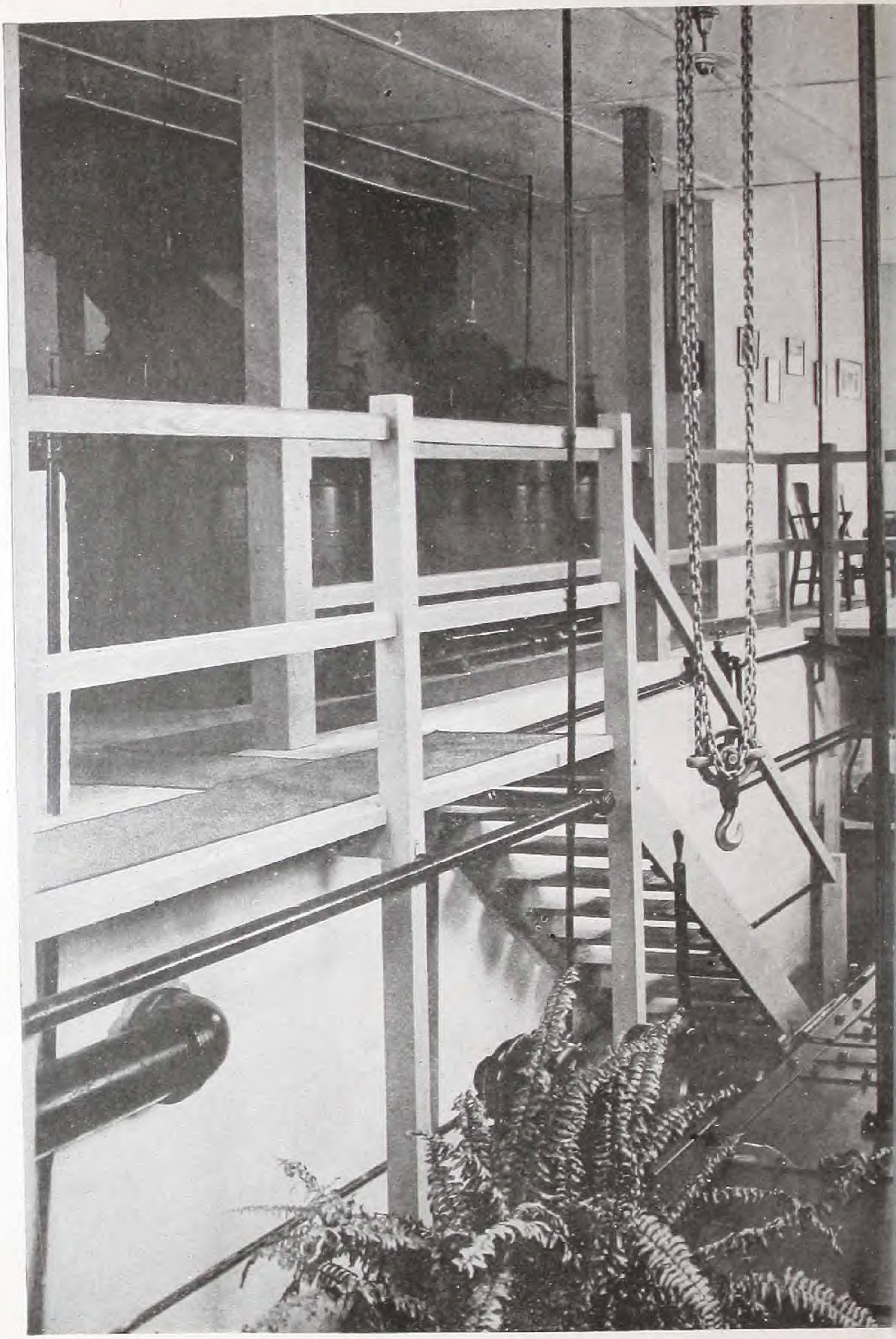
Production of ferric hydrate by this means is very expensive and the results obtained from the use of this method of sewage treatment have not proved satisfactory. The excessive cost for the degree of purification effected and the trouble experienced in the up-keep of equipment have caused wholesale abandonment of plants constructed upon this principle.

THE DIRECT OXIDATION PROCESS.

General Principles.

In this method of electro-chemical treatment *with lime* the essential principles employed are well understood and are based upon certain fundamental laws of chemistry, which can be easily demostrated by a simple laboratory experiment:

> "Two mild steel electrodes are immersed in lime water contained in a glass jar or other vessel; the top is sealed—leaving an opening for drawing off the gaseous products of electrolysis—and the current is applied. Hydrogen and oxygen are liberated (at the negative and positive electrodes respectively) and can be drawn off through the opening provided for that purpose, while the electrodes (if cleaned before being used) will be found to be unaffected—no iron being taken into solution."



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Plant in Operat

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t Easton, Pa.

These simple facts constitute the fundamentals upon which the Direct Oxidation Process is based and the apparatus employed is designed for the purpose of applying these principles to the treatment of municipal sewage.

Application of Principles.

An electric current is passed between mild steel electrodes in sewage that has been rendered alkaline by the addition of quick lime, resulting in the liberation of hydrogen and oxygen within the sewage. These being in the nascent condition, readily attack the organic matter of the sewage, forming water, carbon, dioxide, nitrogen and other simple and inoffensive compounds. The net result of these reactions is the rapid and very complete destruction of organic matter. The electrodes are maintained in a "passive condition" by reason of the alaklinity of the sewage, and no ferric hydrate is formed.

Other Effects of Lime.

Besides maintaining the passivity of the electrodes the lime performs at least three other important functions:

(1) It serves to conduct the current and make possible the liberation of nascent oxygen at a low voltage.

(2) It serves as perhaps the best possible precipitant of the residual organic matter remaining after treatment.

(3) By hydrolysis, it acts on urea and other compounds in solution to form calcium carbonate and ammonium hydrate.

Action of the Current.

In addition to the production of nascent hydrogen and oxygen by electrolysis and its possible action in breaking down complicated organic compounds, the current may serve to neutralize the electrical charges which hold certain colloidal bodies in suspension. Under such conditions these colloids would be precipitated and carried down by the flocculent calcium carbonate formed in the process.

Agitation During Electrolysis.

Revolving paddles are placed between each pair of electrodes to serve a triple purpose:—

(1) To keep the electrode passage free from debris.

(2) To prevent, so far as possible, the accumulation on the electrodes of solid products of electrolysis.

(3) To insure intimate contact of the sewage with the electrodes.

Alternation of Lime Dosage.

In starting up the plant lime water is added to the sewage prior to electrolysis, so that this may be begun in an alkaline medium. (This, as explained above, renders the electrodes passive.) As electrolysis continues calcium carbonate, produced by reaction between the lime and the carbon dioxide produced in the sewage, begins to accumulate and to build up on the electrodes. This tends to obstruct the movement of the revolving paddles and increases their power requirement, the increase being recorded on a watt-meter placed in the power circuit. When the needle of this instrument reaches a certain point the flow of lime water is diverted by changing the valves in the feed line, so that it enters the sewage after electrolysis. The raw sewage, thus allowed to enter the tank, quickly dissolves the deposit of calcium carbonate (without affecting the production of hydrogen and oxygen as the electrodes remain passive), which decreases the power requirement of the paddles and causes the watt-meter to fall back to its original position, at which time the valves are again changed and the lime water is again admitted prior to electrolysis. (It will be appreciated that a continued flow of raw sewage would attack the electrodes, thus destroying them and shortening the life of the equipment as well as cutting down the efficiency of the plant.)

Experience has proved that the best results are obtained when the lime dosage is so regulated that the effluent from the plant contains at least 30 parts per million of lime, expressed as calcium oxide.

The Equipment.

The complete installation consists essentially of the following:

(1) Raw sewage screens.

(2) Electrolytic units.

(3) Electrical equipment.

(4) Lime pulverizer.

(5) Lime storage tank.

(6) Lime feeding equipment (including slaking tanks).

*(7) Settling basins.

*(8) Sand beds, filter presses, drying ovens, or other means of handling the sludge.

The 4th and 5th items need no comment in this article.

Raw sewage as it enters the plant is first run over a bar screen with openings varying from three-fourths to one and one-half inches, depending upon the nature of the sewage. This serves to remove bulky

*It is claimed that the effluent can be safely run into a water course, if desired, without separating the sludge, thus obviating the necessity of settling basins or filters.

objects, trade waste and other material (foreign to the sewage itself), which can be burned or otherwise disposed of. The sewage is then run over a screen or grid having one-quarter inch openings, which removes obstructions and foreign matter that may have passed through the first screen, but is still too bulky to pass through the apparatus, as well as any glass or other gritty material. This material is constantly removed by large moving brushes, which also serve to force any soft material through the grid and so into the apparatus.

The electrodes are housed in a substantially-built cypress tank, the top of which is in two removable sections securely bolted into place and made water-tight with a rubber gasket. It is also provided with vents for removing the gaseous products of electrolysis. The electrodes, consisting of mild steel plates 10 x 16 inches by 3/16 of an inch and spaced 3/8 of an inch apart, are arranged in banks of 48, two banks being placed one above the other. Between each pair of plates are placed two revolving paddles or agitators. These paddles are revolved by insulated shafts passing through holes punched in the plates to receive them. The shafts are motor driven through a double reduction gear box and two lines of bevel gears. (Suitable flexible couplings are provided to take care of any slight warping of the tank.) The speed reduction is 90 to 1, so that a motor speed of 1,800 R. P. M. gives a paddle speed of 20 R. P. M. Each set of paddles having its own gear drive, any tier of electrodes can be readily removed.

The banks of electrodes are placed across the tank, the plates being parallel to the sides. The spaces between the banks and the tank are blocked up so that the liquid is forced to pass through the three-eights inch spaces between plates eleven successive times. This, together with the mechanical agitation, means that the sewage is continuously exposed to the electrode surface. There is an approximate total of 863 square feet each of effective positive and negative electrode surface to each unit.

The twenty-two banks of electrodes being connected in series, a standard generator can be used, thus obviating the special machinery required when the multiple system is used. The low amperage used, as compared to the multiple arrangement, allows the installation of smaller conductors. The accidental short-circuiting of any bank in the series automatically increases the current density of the remaining banks by decreasing the resistance. In the multiple arrangement such a condition would necessitate a complete shut-down.

The electrical equipment consists of the motors required to operate the various devices; the motor-generator set, which furnishes the cur-

rent for electrolysis; voltmeter; ammeter and rheostat for control of the electrolyzing current; a double throw switch for reversing polarity of the electrodes when desired; a circuit-breaker for protection in case of emergency; and a watt-meter to record the power consumption of the rotating paddles.

The lime feeding equipment is motor driven and embodies a very cleverly-designed automatic feed, whereby the desired amount of pulverized quick-lime is fed into the slaking tanks. This feeding device is capable of eighty-seven adjustments, giving a range of feed from 600 pounds to ten tons in twenty-four hours. The lime is slaked with a portion of the effluent from the process.

Possible Advantages of the Equipment.

(1) *Direct, Positive and Controlled Operation of the Process Is Possible.* The addition of the lime and the application of the current being under the control of the operator, it would seem that the operation of the plant depends primarily upon the excellence of the machinery and the integrity and ability of the operator.

(2) *High Efficiency in the Destruction of the Solid Organic Material and in the Disinfection and Purification of the Effluent.* The action of nascent hydrogen and oxygen—if properly controlled—and the presence of a sufficient quantity of the mineral base calcium will go far toward the formation of neutral salts or other inoffensive and stable compounds and the prevention of offensive odors, due to the putrefactive fermentation which takes place in raw sewage. It should also result in a high degree of disinfection or bacterial removal.

(3) *Compact Character of Equipment.* The apparatus, as designed, is compact and easily handled, occupying but a small amount of floor space—a one-unit plant being easily housed in a building about twenty by forty feet. (This, of course, being exclusive of any settling basins or other methods of handling the effluent.)

(4) *Reduction in the Need for Long Trunk Sewers.* A plant of such small size, which was free from objectionable odors and had been proved to be efficient in its operation, might well be located on any vacant lot within the city limits. It is well known that the majority of sewage disposal plants must be isolated because of the many objectionable features.

(5) *Ecomony in the Matter of a Bonded Debt Is Possible.* An engineer's estimate on a proposed installation to treat four million gallons of sewage per day by the Direct Oxidation Process method was $200,000.00 for the complete plant, in readiness to operate. Another system

was proposed by prominent engineers, in accordance with bacteriological methods, at a cost of $763,000.00, *exclusive of a two-mile trunk sewer*. Neglecting the additional cost of this trunk sewer, and estimating the daily cost of operation as being $10.00 per million gallons for the Direct Oxidation Process and $3.00 per million gallons for the bacteriological process, it is interesting to compare these bids from the viewpoint of a tax-payer, who would bear his share of a seven and one-half per cent interest and funding charge on municipal bonds issued for the purchase of a sewage disposal plant.

Interest charges on bonds:

$7\frac{1}{2}\%$ of $763,000 equals $57,225.00.

$7\frac{1}{2}\%$ of $200,000 equals $15,000.00.

Difference in favor of $200,000.00 plant equals $42,225.00.

Cost of operation:

4,000,000 gallons per day at $10.00 per million, equals $40.00 per day.

4,000,000 gallons per day, at $3.00 per million, equals $12.00 per day.

Difference in favor of $763,000.00 plant equals $28.00 per day or $9,220.00 per year.

$42,225.00
9,220.00

$33,005.00 equals net annual saving in favor of the Direct Oxidation Process.

(The additional cost of the two-mile trunk sewer necessary for the more costly plant, if taken into account, would show a still larger saving possible by the Direct Oxidation Process.)

This would indicate that, if necessary, another Direct Oxidation plant of the same size could be built in about eight years with no more expense to the community than would be involved in paying for the original installation of the more expensive plant.

Results Obtained and Comments of Observers.

A single unit plant at Easton, Pa., has been in demonstration operation for about two years and has given very satisfactory results in the treatment of domestic sewage at such times as it has been operated. It is situated on a residence street of the city and has given no offense to adjoining property owners. This plant has been investigated by health officials, engineers, and scientific investigators. Numerous tests and determinations have been made by officials of Departments

of Health and others. It has been found that the solid residue or "sludge" from this process is usually of a light gray color; is flocculent, and settles rapidly; smells slightly of ammonia when moist, and has the odor of fresh earth when dry. When filter pressed it contains approximately sixty per cent of moisture; its composition depending upon the nature of the raw sewage and varying with local conditions.

Dr. John A. Roddy, formerly Professor of Bacteriology of the Philadelphia College of Pharmacy, made bacteriological examinations upon the effluent from this process, and wrote in part as follows:

> "The results of the experiments on the electrolytic-lime process would indicate that sedimentation is unnecessary, because the sludge, after an incubation of four days at 37° C. has been found to be stable, and the bacterial tests show the absence of intestinal bacteria. It is my opinion that the effluent from the apparatus could and should be discharged directly into the water-course upon which the plant is located.
>
> "The chief constituent of the sludge is calcium carbonate, which, when discharged into the stream, would act as a corrective for foul bottoms."

The findings of the Department of Health of the State of Pennsylvania, as shown by their report, were that the combined effluent and sludge were in all cases stable and non-putrefactive, thus indicating a high degree of purification. The dissolved oxygen tests of the Franklin Institute showed a loss of but 77-100 parts per million in five days, thus emphasizing the stability of the liquid and sludge.

Conclusion.

The Direct Oxidation Process for the treatment of municipal sewage is a new development in this field of endeavor and is operated upon principles differing essentially from those in general use.

It possesses several possible advantages over other systems, which should be studied from the view-point of efficiency and reliability.

*At least one demonstration plant has given satisfactory results in the hands of the inventor, his associates and others.

The National Lime Association has no financial interest in, or connection with, the new process and presents this paper as a progress report upon a process worthy of the consideration of those persons who are interested in improving methods of sewage treatment.

*Based upon the performance of this plant, at least two cities are now installing the system for permanent use.

The National Lime Association will be glad to discuss with you any problems touching the use of lime in the field of Chemistry, Construction, or Agriculture, and to send you any of the publications listed on the opposite page. These will be sent free of charge, except as noted.

PUBLICATIONS
OF THE
NATIONAL LIME ASSOCIATION

CONSTRUCTION DEPARTMENT.

No.		
	History, Manufacture and Uses of Hydrated Lime, by E. W. Lazell, Ph.D. (vellum bound) ....50c....	98 pages.
	Better Plastering and Better Acoustics, by Lawrence Hitchcock (vellum bound) ....35c....	36 pages.
	Improving Concrete Roads	24 pages.
	Field Test of Hydrated Lime in Concrete Roads	8 pages.
	Auditorium Acoustics	12 pages.
	Standard Specifications for Lime Plaster	20 pages.
300	Ideal Brick Mortar	32 pages.
301	Water-Tight Concrete	24 pages.
302	Improving Cement Products	12 pages.
303	Test Data on Lime in Concrete and Mortar	20 pages.

AGRICULTURAL DEPARTMENT.

100	What is Agricultural Lime?	4 pages.
101	Forms and Equivalent Strengths of Liming Materials	4 pages.
102	Calculating the Cost of Liming Materials	4 pages.
103	Beneficial Effects of Lime on the Soil	4 pages.
104	Methods of Applying Lime To the Soil	4 pages.
105	Need for Lime by Soils of the U. S.	4 pages.
106	Burnt Lime vs. Limestone for Use on Soil	4 pages.
107	Does Burnt Lime Destroy Humus?	4 pages.

CHEMICAL DEPARTMENT

200	A New Method of Sewage Disposal	16 pages.

OTHERS IN PROCESS